CLAIMS

We Claim:

1. A spatial light modulator comprising:

an array of micro-mirrors on a substrate, each micro-mirror of the array comprising a reflective mirror plate held by a hinge on the substrate, wherein the mirror plate and hinge extend substantially parallel to the substrate when the mirror plate is in an undeflected position, wherein the hinge is a multilayer hinge having a first and second layer wherein the first layer is more electrically conductive than the second layer, and wherein the first layer is more narrow than the second layer in a direction substantially parallel to the substrate.

2. The device of claim 1, wherein the first layer comprises an early transition metal.

3. The device of claim 2, wherein the early transition metal is a compound or alloy of titanium.

4. The device of claim 1, wherein the second layer comprises silicon.

5. The device of claim 4, wherein the first layer comprises a transition metal.

6. The device of claim 5, wherein the first layer comprises an early transition metal.

7. The device of claim 1, wherein the second layer is silicon oxide, silicon carbide, silicon nitride or polysilicon.

8. The device of claim 1, wherein the second layer has a resistivity higher than 10^{12} $\mu\Omega\cdot$cm.

9. The device of claim 1, wherein the first layer has a resistivity lower than 100,000 $\mu\Omega\cdot$cm.

10. The device of claim 8, wherein the bottom metal layer has a resistivity lower than 100,000 μΩ•cm.

11. The device of claim 1, wherein the first layer comprises a material with a higher creep rate than the second layer over the operating temperature of the device.

12. The device of claim 1, wherein the first layer covers the second layer by 50% or less of a top surface of the second layer.

13. The device of claim 1, wherein the second layer comprises a compound of silicon and the first layer comprises a compound of an early transition metal.

14. The device of claim 13, wherein the first layer comprises titanium nitride and the second layer comprises silicon nitride.

15. The device of claim 1, further comprising a third layer on an opposite side of the second layer from the first layer.

16. The device of claim 15, wherein the third layer comprises an early transition metal.

17. The device of claim 16, wherein the early transition metal is a compound or alloy of titanium.

18. The device of claim 15, wherein the second layer comprises silicon.

19. The device of claim 18, wherein the third layer comprises a transition metal.

20. The device of claim 19, wherein the first layer comprises an early transition metal.

21. The device of claim 15, wherein the second layer is silicon oxide, silicon carbide, silicon nitride or polysilicon.

22. The device of claim 15, wherein the second layer has a resistivity higher than 10^{12} $\mu\Omega\cdot$cm.

23. The device of claim 15, wherein the first and/or third layers have a resistivity lower than 100,000 $\mu\Omega\cdot$cm.

24. The device of claim 15, wherein both the first and third layers have a resistivity lower than 100,000 $\mu\Omega\cdot$cm.

25. The device of claim 15, wherein the first and third layers comprise a material with a higher creep rate than the second layer over the operating temperature of the device.

26. The device of claim 1, wherein the first layer covers the second layer by 50% or less of a top surface of the second layer and the third layer covers the second layer by 50% or less of a bottom surface of the second layer.

27. The device of claim 15, wherein the second layer is a multilayer structure comprising a plurality of layers of insulating materials.

28. The device of claim 1, wherein the first layer covers the second layer by 33% or less of a top surface of the second layer.

29. The device of claim 1, wherein the first layer covers the second layer by 25% or less of a top surface of the second layer.

30. The device of claim 1, wherein the first layer covers the second layer by 33% or less of a top surface of the second layer and the third layer covers the second layer by 33% or less of a bottom surface of the second layer.

31. The device of claim 1, wherein the first layer covers the second layer by 25% or less of a top surface of the second layer and the third layer covers the second layer by 25% or less of a bottom surface of the second layer.

32. The device of claim 1, wherein the hinge is a substantially elongated torsion hinge.

33. The device of claim 32, wherein the torsion hinge has a length and width, wherein the first layer is more narrow along the width of the hinge than the second layer.

34. A spatial light modulator comprising:

an array of micro-mirrors on a substrate, each micro-mirror of the array comprising a reflective mirror plate held by a hinge on the substrate at the contact, wherein the mirror plate and hinge extend substantially parallel to the substrate when the mirror plate is in an undeflected position, wherein the hinge is a multilayer hinge having a first and second layer wherein the first layer has a creep rate higher than that of the second layer at the operating temperature of the spatial light modulator, and wherein the first layer is more narrow than the second layer in a direction substantially parallel to the substrate.

35. The device of claim 34, wherein the first layer comprises an early transition metal.

36. The device of claim 35, wherein the early transition metal is a compound or alloy of titanium.

37. The device of claim 34, wherein the second layer comprises silicon.

38. The device of claim 37, wherein the first layer comprises a transition metal.

39. The device of claim 38, wherein the first layer comprises an early transition metal.

40. The device of claim 34, wherein the second layer is silicon oxide, silicon carbide, silicon nitride or polysilicon.

41. The device of claim 34, wherein the second layer has a resistivity higher than 10^{12} $\mu\Omega\cdot$cm.

42. The device of claim 34, wherein the first layer has a resistivity lower than 100,000 $\mu\Omega\cdot$cm.

43. The device of claim 41, wherein the bottom metal layer has a resistivity lower than 100,000 $\mu\Omega\cdot$cm.

44. The device of claim 34, wherein the first layer comprises a material with a higher electrical conductivity than the second layer.

45. The device of claim 34, wherein the first layer covers the second layer by 50% or less of a top surface of the second layer.

46. The device of claim 34, wherein the second layer comprises a compound of silicon and the first layer comprises a compound of an early transition metal.

47. The device of claim 46, wherein the first layer comprises titanium nitride and the second layer comprises silicon nitride.

48. The device of claim 34, further comprising a third layer on an opposite side of the second layer from the first layer.

49. The device of claim 48, wherein the third layer comprises an early transition metal.

50. The device of claim 49, wherein the early transition metal is a compound or alloy of titanium.

51. The device of claim 48, wherein the second layer comprises silicon.

52. The device of claim 51, wherein the third layer comprises a transition metal.

53. The device of claim 52, wherein the first layer comprises an early transition metal.

54. The device of claim 48, wherein the second layer is silicon oxide, silicon carbide, silicon nitride or polysilicon.

55. The device of claim 48, wherein the second layer has a resistivity higher than 10^{12} μΩ•cm.

56. The device of claim 48, wherein the first and/or third layers have a higher creep rate than the second layer.

57. The device of claim 48, wherein both the first and third layers have a higher creep rate than the second layer.

58. The device of claim 48, wherein the first and third layers comprise a material with a higher creep rate and a higher electrical conductivity than the second layer over the operating temperature of the device.

59. The device of claim 34, wherein the first layer covers the second layer by 50% or less of a top surface of the second layer and the third layer covers the second layer by 50% or less of a bottom surface of the second layer.

60. The device of claim 48, wherein the second layer is a multilayer structure comprising a plurality of layers of ceramic films.

61. The device of claim 34, wherein the second layer is a multilayer structure comprising a plurality of layers of ceramic films.

62. The device of claim 34, wherein the first layer covers the second layer by 33% or less of a top surface of the second layer.

63. The device of claim 34, wherein the first layer covers the second layer by 25% or less of a top surface of the second layer.

64. The device of claim 34, wherein the first layer covers the second layer by 33% or less of a top surface of the second layer and the third layer covers the second layer by 33% or less of a bottom surface of the second layer.

65. The device of claim 34, wherein the first layer covers the second layer by 25% or less of a top surface of the second layer and the third layer covers the second layer by 25% or less of a bottom surface of the second layer.

66. A method of making a micro-mirror device, the device comprising a hinge and a micro-mirror plate attached to the hinge such that the micro-mirror plate can rotate relative to the substrate by the hinge, the method comprising:

providing a substrate;

depositing a first sacrificial layer on the substrate;

forming either a hinge or a micro-mirror plate on the first sacrificial layer;

depositing a second sacrificial layer ;

forming a micro-mirror plate or hinge on the second sacrificial;

wherein the forming of the hinge on either the first or second sacrificial layer comprises:

depositing a second layer comprised of a material with a creep rate lower than that of the first layer;

depositing a first layer that comprises a material with a creep rate higher than that of the second layer;

patterning the first layer so as to have a width that is 50% or less of the width of the second layer; and

forming a hinge support to connect the hinge directly or indirectly to the substrate; and

removing the first and second sacrificial layers so as to release the micro-mirror device.

67. The method of claim 66, wherein the forming of the hinge further comprises:

depositing a third layer prior to depositing the second layer, the third layer comprised of a material with a creep rate greater than that of the second layer at the operating temperature of the device.

68 The method of claim 67, wherein prior to depositing the second first layer is patterned to have a width less than the width of the second layer after patterning.

69 The method of claim 68, wherein the third layer is patterned to have a width that is 50% or less of the width of the second layer after patterning.

70. The method of claim 66, wherein the first and third layers are patterned to have widths of 33% or less of the width of the second layer after patterning.

71. The method of claim 70, wherein the first and third layers are patterned to have widths of 25% or less of the width of the second layer after patterning.

72. A method of making a micro-mirror device, the device comprising a hinge and a micro-mirror plate attached to the hinge such that the micro-mirror plate can rotate relative to the substrate by the hinge, the method comprising:

providing a substrate;

depositing a first sacrificial layer on the substrate;

forming either a hinge or a micro-mirror plate on the first sacrificial layer;

depositing a second sacrificial layer ;

forming a micro-mirror plate or hinge on the second sacrificial;

wherein the forming of the hinge on either the first or second sacrificial layer comprises:

depositing a second layer comprised of a material with a resistivity higher than 10^{12} $\mu\Omega{\circ}cm$ at the operating temperature of the device;

depositing a first layer that comprises a material with a resistivity less than that of the second layer;

patterning the first layer so as to have a width that is 50% or less of the width of the second layer; and

forming a hinge support to connect the hinge directly or indirectly to the substrate; and

removing the first and second sacrificial layers so as to release the micro-mirror device.

73. The method of claim 72, wherein the forming of the hinge further comprises: depositing a third layer prior to depositing the second layer, the third layer comprised of a material with a resistivity less than that of the second layer.

74. The method of claim 73, wherein prior to depositing the second layer the third layer is patterned to have a width less than the width of the second layer after patterning.

75. The method of claim 74, wherein the third layer is patterned to have a width that is 50% or less of the width of the second layer after patterning.

76. The method of claim 73, wherein the first and third layers are patterned to have widths of 33% or less of the width of the second layer after patterning.

77. The method of claim 76, wherein the first and third layers are patterned to have widths of 25% or less of the width of the second layer after patterning.

78. A method of making a micro-mirror device, the device comprising a hinge and a micro-mirror plate attached to the hinge such that the micro-mirror plate can rotate relative to a substrate by the hinge, the method comprising:

providing the substrate;

depositing a first sacrificial layer on the substrate;

forming the micro-mirror plate on the first sacrificial layer;

depositing a second sacrificial layer on the micro-mirror plate;

patterning the second sacrificial layer according to a structure of the hinge;

forming the hinge on the patterned second sacrificial layer, further comprising:

depositing a bottom layer that comprises a material with resistivity higher than 10^{12} $\mu\Omega\circ$cm at the operating temperature of the device;

depositing a top layer that comprises a material with resistivity lower than 100,000 $\mu\Omega\circ$cm at the operating temperature of the device;

narrowing the topmost layer to cover at least 50% of the bottom layer surface by means of patterning and/or etching; and

providing a means to connect the bottom and top layers directly or indirectly to the substrate; and

removing the first and second sacrificial layers so that the bottom and top layers are free to move relative to the substrate.

79 The method of claim 78, wherein the hinge further comprises:

depositing a bottom layer comprised of a material with resistivity lower than 100,000 $\mu\Omega\circ$cm at the operating temperature of the device;

depositing an intermediate layer that comprises a material with resistivity higher than 10^{12} $\mu\Omega\circ$cm at the operating temperature of the device;

depositing a top layer that comprises a material with resistivity lower than 100,000 $\mu\Omega\circ$cm at the operating temperature of the device;

narrowing the topmost layer to cover at least 50% of the bottom layer surface by means of patterning and/or etching; and

providing a means to connect the bottom, intermediate, and top layers directly or indirectly to the substrate.

80. A method of making a micro-mirror device, the device comprising a hinge and a micro-mirror plate attached to the hinge such that the micro-mirror plate can rotate relative to a substrate by the hinge, the method comprising:

providing the substrate;

depositing a first sacrificial layer on the substrate;

forming the micro-mirror plate on the first sacrificial layer;

depositing a second sacrificial layer on the micro-mirror plate;

patterning the second sacrificial layer;

forming the hinge on the patterned second sacrificial layer so as to connect to both the micro-mirror plate and the substrate, the forming the hinge comprising:

depositing a layer that comprises an electrical conductor;

depositing a layer that comprises an electrical insulator;

depositing a layer that comprises an electrical conductor, wherein at least one of the electrical conductor layers has a width 50% or less than that of the width of the insulator; and

removing the first and second sacrificial layers such that the micro-mirror plate is free to move relative to the substrate.

81. The method of claim 80, wherein the insulator layers comprise silicon nitride.

82. The method of claim 80, wherein the insulator layers comprise silicon oxide or silicon carbide.

83. The method of claim 80, wherein the conducting layers comprise titanium.

84. The method of claim 80, wherein the conducting layers comprise a titanium alloy or titanium compound.

85. A micromirror device, comprising:

a substrate;

a mirror plate; and

a hinge, to which the mirror plate is attached such that the mirror plate rotates along the hinge, the hinge further comprising:

a first layer having a first stress gradient;

a second layer formed on and contact the first layer such that the first layer has a stress gradient that is less than the first stress gradient.

86. The device of claim 85, wherein the first layer has a principal axis and the second layer has a second principal axis; and wherein the first and second axes are not aligned when viewed from the top of the two layers.

87. The device of claim 85, wherein the second hinge layer has a width that is shorter than a width of the first layer.

88. The method of claim 85, wherein the hinge further comprises:

a third layer on which the first layer is formed, wherein the third layer has a width that is shorter than a width of the first layer.

89. The method of claim 88, further comprising:

a fourth layer disposed on the three layers including the first, second and third layers such that the three layers are wrapped by the fourth layer.

90. The device of claim 1, wherein the width of the first layer of the multilayer hinge is non-uniform along the length of the first layer.

91. The device of claim 90, wherein the second layer of the multilayer hinge is non-uniform along the length of the second layer.

92. A microelectromechanical device comprising:

a movable element on a substrate, each movable element comprising a plate held by a hinge on the substrate, wherein the plate and hinge extend substantially parallel to the substrate when the plate is in an undeflected position, wherein the hinge is a multilayer hinge having a first layer that is more electrically conductive than a second layer, and wherein the first layer is more narrow than the second layer in a direction substantially parallel to the substrate.